# EFFECTS OF PRECOOKING ON DRIED MUTTON MINCE



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# EFFECTS OF VARIOUS PRECOOKING PROCEDURES ON INITIAL QUALITY AND QUALITY AFTER STORAGE OF DRIED MUTTON MINCE

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*Summary*

A wide variety of precooking procedures in relation to production of dried mutton mince have been investigated. In respect of quality and storage life an attempt was made to assess the relative importance of a number of factors such as cooking "on" and "off" the bone, size of pieces of meat, and different methods, temperatures, and times of cooking. It was concluded that the cooking of boneless pieces in live steam at atmospheric pressure for a period of approximately 45 min was the most satisfactory procedure. This finding applied to the meat from mature to aged beasts for two-stage through-draught drying, when the cooking liquors were not returned to the mince.

## I. Introduction

Considerable quantities of dehydrated mutton mince were produced in Australia during World War II by a method devised to economize both in skilled labour and strategic materials. This method, which involved high-pressure steam cooking of roughly jointed carcasses, resulted in a product unsuitable for compression and containing an off-flavour termed "pressure-cooked flavour". Therefore it was decided, early in 1947, to investigate in detail problems associated with the production of good-quality dried mutton mince from Australian Merino and crossbred carcasses, particularly from old sheep.

Investigations on precooking reported by Bate-Smith, Lea, and Sharp (1943) were concerned mainly with dehydration of beef. They concluded that precooking was essential, the uncooked meat yielding a hard, gritty product. Two methods of cooking were compared: pressure cooking with steam pressures up to 15 lb/sq. in., and cooking in boiling water. Cooking either in boiling water or in steam of 1–2 lb/sq. in. with a short cooking time was satisfactory.

Sharp (1953) cooked several batches of meat in the same liquor (serial cooking), and found that the texture was not different from the standard product and that the flavour of the third batch was equal to the standard, to which concentrated liquors had been added. In the same report Sharp described tests of varying degrees of pressure cooking on quality of dried mutton. He concluded that 2 hr at 12 lb/sq. in. of steam would appear to be the maximum degree of cooking which meat will stand without an alteration in flavour. It will be shown later in the present paper that pressures in excess of 3 lb/sq. in. for short times will result in changes in flavour.

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The United States Department of Agriculture (1944) reports that meat precooked at the relatively low temperature of 165°F was somewhat more acceptable than that precooked at 212°F, when dried by the vacuum rotary process. However, the dehydrated meat retained its palatability better during storage when pretreated at the higher temperature.

Pearce (1943) compared four precooking procedures for dehydration of pork. These were minced boned meat cooked at 15 lb/sq. in., slashed meat on the bone at 200–220°F in a retort, boned pieces about 1 lb in weight cooked at 15 lb/sq. in. with subsequent addition of concentrated liquor, and finally a dry cooking method at 15 lb/sq. in. of steam in the jacket of the cooker. No significant differences in palatability were detected between samples of meat cooked by the four methods, but the last one was considered to be the most suitable for dehydration because it gave meat of low water content.

Precooking in boiling water was most commonly used in commercial practice during World War II, except in countries such as Australia where certain economic factors demanded a different procedure.

## II. Experimental

### (a) *Equipment*

A cylindrical pressure vessel 2 ft 4 in. in diameter and 4 ft long was used for cooking in steam. This vessel contained two rows, each of two trays 4 sq. ft. in area. The bottoms of the trays were constructed with coarse monel mesh to allow adequate penetration of the live steam. A stainless steel tray was set under the lower bank of trays to collect the exuding liquor and condensate from the meat. Adequate provision was made for venting of entrapped air and for even distribution of the steam throughout the meat. Pressure control was effected automatically with a Cambridge pneumatic recorder and controller of fixed high sensitivity.

Water cooking was done in a covered stainless steel kettle with a removable steam coil set on the bottom. The meat was placed in a perforated stainless steel basket of 14 in. diameter and 16 in. depth. For temperatures below 212°F a Cambridge recorder controller was used.

Cooking procedures in fat or in water with live steam for heating were carried out by placing the meat in stainless steel buckets, covering with fat or water as required, and placing the buckets in the pressure vessel with the trays removed.

The fat separator used for separating the fat from the cooking liquors was a gravity type consisting of a vertical stainless steel cylindrical vessel 21 in. long and 6·5 in. diameter. A sight glass and cock was attached to the bottom of the cylinder. For those cooking methods where pieces of meat were cooked in fat, the separation of the fat was made by draining with a sieve.

A Hecla domestic electric oven with thermostat was used for cooking by roasting.

A Denison No. 2 worm-feed motor-driven mincer was used for the mincing treatments. The plates were 5 in. in diameter and the knives were four-bladed. The mincer was driven at approximately 60 r.p.m. to limit damage to the meat particles.

The dryer (Fig. 1) used was an up-draught batch dryer with provision for partial or total recirculation of the air. Dry-bulb temperatures were controlled by a Taylor pneumatic controller recorder with variable sensitivity, automatic reset, and pre-act. The humidity was kept at a low level by adequate venting. Fan revolutions could be varied by means of a friction-drive variable speed gear. The meat was placed in a stainless steel tray 4 sq. ft. in area, the bottom of which was covered with "Monel" gauze. More than one treatment could be dried at the one time by dividing the tray with stainless steel partitions. The air speed was approx. 120 ft/min.

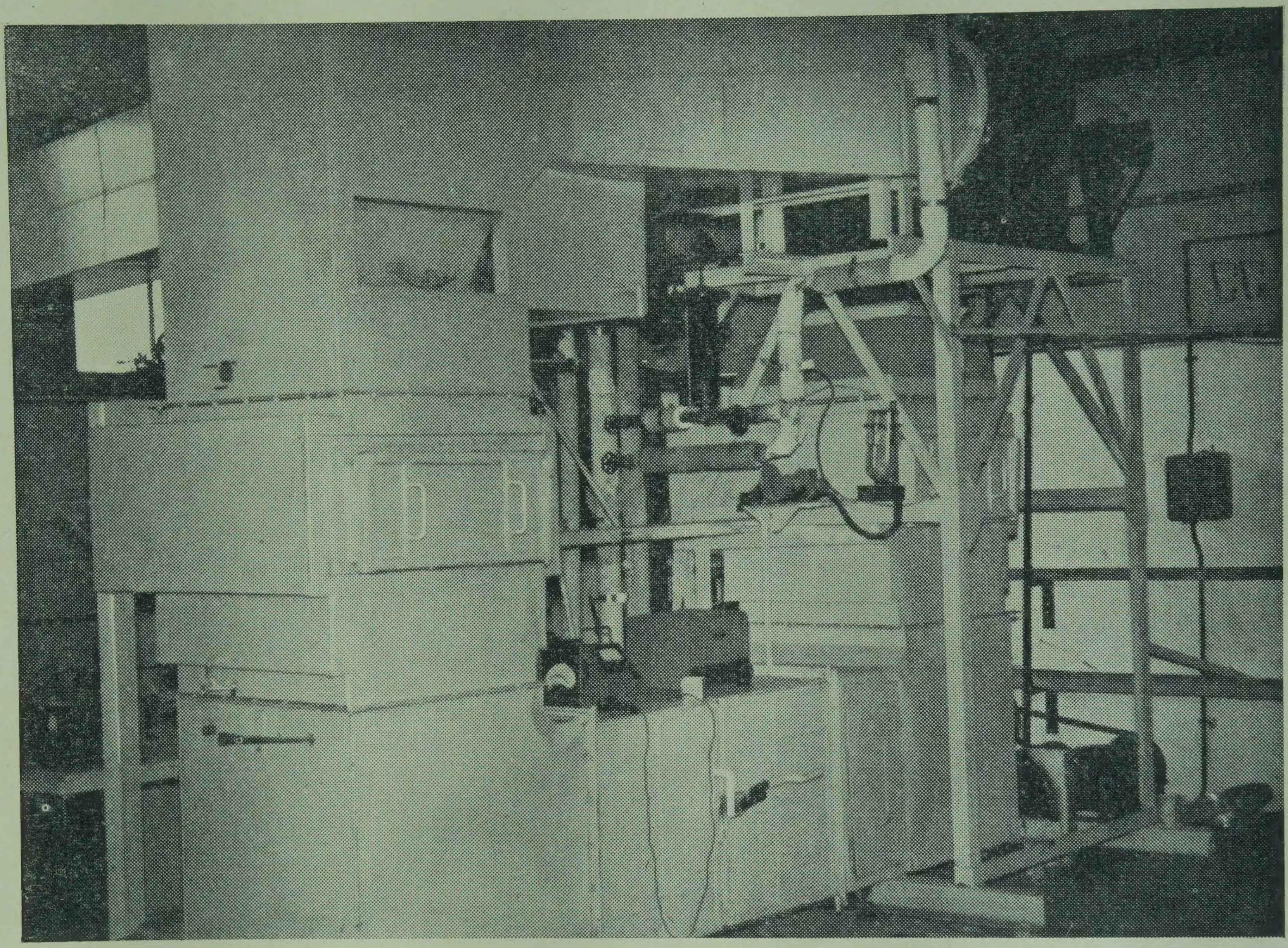

Fig. 1.—Dryer used for preparation of samples.

### (*b*) *Preparation of Material*

The investigations were carried out in three parts, the identity of which will be retained throughout the paper. The first section was concerned mainly with a series of general investigations and included four methods of cooking; the second section contained 16 different methods of cooking of boneless meat; and the third section concerned cooking on the bone.

In the early stages of drying, referred to as the primary stage, it was possible to use reasonably high dry-bulb temperatures without the meat temperature exceeding the safe limit. However, in the later stages of drying, referred to as the secondary

stage, the dry-bulb temperature was reduced because of the increase in the meat temperature. Often in commercial practice loading rates are increased considerably in the secondary drying stage, e.g. in a two-stage through-draught belt dryer.

(i) *First Section.*—This section included two grades of mutton—second-grade export and top canner; two mincing treatments, mincer plates with holes $\frac{3}{16}$ and $\frac{1}{2}$ in. in diameter; and two drying treatments, secondary drying temperatures being 140 and 135°F.

The two drying treatments commenced with an initial air temperature of 155°F, dropping by steps of 5°F each 15 min until the secondary drying temperature was reached.

TABLE 1

SECOND SECTION: DETAILS OF COOKING METHODS

| Cook No. | Size of Meat | Cooking Medium | Method of Heating | Pressure (lb/sq. in.) | Cooking Time (min) A | B | C | D |
|---|---|---|---|---|---|---|---|---|
| 1 | Boned pieces | — | Live steam | 20 | 15 | 30 | 50 | 75 |
| 2 | ,, ,, | Boiling water | Steam | — | 30 | 60 | 90 | 120 |
| 3 | ,, ,, | — | Live steam | 3 | 20 | 40 | 60 | 80 |
| 5 | ,, ,, | — | ,, ,, | 15 | 15 | 30 | 60 | 90 |
| 6 | ,, ,, | — | ,, ,, | 10 | 15 | 30 | 60 | 90 |
| 7 | ,, ,, | — | ,, ,, | 0 | 30 | 60 | 90 | 120 |
| 8 | Mince | Water | ,, ,, | 0 | 30 | 60 | 90 | 120 |
| 9 | Boned pieces | ,, | ,, ,, | 5 | 30 | 56 | 82 | 108 |
| 10 | Mince | — | ,, ,, | 0 | 30 | 60 | 90 | 120 |
| 12 | Boned pieces | Mutton fat | Elec. oven 350–450°F | — | 30 | 50 | 70 | 90 |
| 13 | ,, ,, | Water (195°F) | Steam | — | 30 | 60 | 90 | 120 |
| 14 | ,, ,, | Mutton fat | Live steam | 20 | 30 | 56 | 82 | 108 |
| 15 | ,, ,, | ,, ,, | ,, ,, | 0 | 30 | 53 | 76 | 99 |
| 16 | ,, ,, | ,, ,, | ,, ,, | 10 | 30 | 55 | 80 | 105 |
| 17 | ,, ,, | ,, ,, | ,, ,, | 30 | 30 | 55 | 80 | 105 |
| 18 | ,, ,, | Beef fat | ,, ,, | 10 | 30 | 55 | 80 | 105 |

The design chosen was a factorial one on grade, mince, and drying treatments; each combination formed a unit, which was split into the same four cooking treatments. The four methods of cooking were numbered 1–4 in the following order:

(1) half carcasses were divided into forequarter, flank, and hindquarter and cooked on the bone in live steam at 20 lb/sq. in. for 75 min;

(2) cooking in boiling water was carried out for 40 min using boned pieces approximately 3 in. cube;

(3) live steam at 3 lb/sq. in. was used with similar pieces;

(4) this was identical with the second except for a cooking time of 80 min.

In dividing the two carcasses between the four cooking treatments it was necessary to keep one side intact for cooking on the bone, and this left one side for each of the three remaining cooking treatments. The final comparison between

cooking methods was influenced in a random way by carcass-to-carcass variation; the number of carcasses used, however, was small. No cooking liquors were returned to the meat. The eight combinations were replicated three times.

For storage purposes 100-g samples were placed in 1-pt lever lid cans, sealed with wax, and placed in a constant temperature room at 86°F for periods of 4, 12, and 24 weeks.

(ii) *Second Section*.—The design used 16 different cooking treatments with four periods of cooking, the times depending on the severity of cooking in each case. (See Table 1 for details of the treatments.)

Table 2

THIRD SECTION: DETAILS OF COOKING TREATMENTS

| Part | Cooking Treatment | Cooking Time (min) | Size of Pieces (in.) | Boned or Unboned |
|---|---|---|---|---|
| A | Live steam 3 lb/sq. in. | 180 | 2 | On bone |
| | | 180 | 4 | ,, |
| B | ,, | 110 | 2 | ,, |
| | | 110 | 4 | ,, |
| | | 140 | 4 | ,, |
| | | 140 | 2 | ,, |
| C | Live steam atmospheric pressure | 120 | 2 | ,, |
| | | 120 | 4 | ,, |
| | | 240 | 4 | ,, |
| | | 240 | 2 | ,, |
| D | ,, | 150 | 2 | ,, |
| | | 150 | 4 | ,, |
| | | 180 | 4 | ,, |
| | | 180 | 2 | ,, |
| E | ,, | 150 | Large | ,, |
| | | 180 | ,, | ,, |
| F | ,, | 150 | ,, | ,, |
| | | 150 | ,, | Off bone |

Each day, two third-grade export carcasses were boned and the pieces divided into four equivalent groups by distributing the leg meat, the flank meat, and the shoulder meat from each half carcass in turn. The cooking treatment was selected at random from the 16 possibilities and the four cooking periods were applied one to each of the four equivalent groups of meat. After cooking, the meat was minced through a plate with $\frac{5}{16}$-in. diameter holes and, as in the first section, no cooking liquors were readded.

The initial drying temperature was 155°F, dropping by 5°F each 15 min for 1 hr, followed by a secondary drying temperature of 135°F.

Storage samples, packed in the same way as in the first section, were placed in a constant temperature room at 77°F for periods of 3 and 6 months.

(iii) *Third Section.*—The main purpose of these experiments was to investigate the possibility of producing a satisfactory product from unboned meat; two cooking methods were selected from the previous section. In the determination of a satisfactory product, ease of boning must be considered as well as initial quality and quality after storage.

Details of design are shown in Table 2. There were six parts (A–F) of the experiments with three replications in each. Two top canner-grade carcasses provided the material for one replicate in each part and these were divided into two or four representative portions by equal distribution of each part of the carcasses.

Table 3

PALATABILITY SCORING SCALES

| | Characteristic | Points |
|---|---|---|
| Flavour | Meat flavour | 8–0 |
| | Off-flavours: staleness, pressure-cooked, burnt, foreign | 0–8 |
| Texture | Particle size | 8–0 |
| | Fatness | 8–0 |
| | Juiciness | 8–0 |
| | Tenderness | 8–0 |
| | Woolliness | 0–8 |
| General | Colour | 8–0 |
| | Grade | 4–0 |

The bones were removed by hand after precooking and the meat was minced through a plate with $\frac{3}{8}$-in. diameter holes. The drying procedure was similar to that of the second section. Storage samples were held for 3 and 6 months at a temperature of 77°F.

### (*c*) *Methods of Analyses*

(i) *Moisture Content.*—These were determined in duplicate using 5–7 g of mince. The weighed samples were dried for 16 hr in an air oven at a temperature of 212°F.

(ii) *Fat Estimations.*—Soxhlet extractions with light petroleum ether (b.p. 86–158°F) were continued for 4 hr and, after removal of most of the solvent, the fats were dried in a vacuum oven for 1 hr at a temperature of 131°F and a pressure not in excess of 2 cm of mercury.

(iii) *Bacteriological Counts.*—Counts were made on nutrient agar plates incubated for 48 hr at 98°F. Frequent counts gave a good check on the hygiene of processing.

(iv) *Organoleptic Tests.*—Samples (30 g) of meat were covered with 120 ml of hot 0·5 per cent. solution of sodium chloride, allowed to simmer on a hot plate for 1 hr, and then placed for 30 min in an air oven at a temperature of 212°F. The

excess liquor was drained off and the samples were tasted "blindfold" by a trained panel. In later work (Prater 1953) an atmospheric steamer was used for reconstitution and this allowed better control and required less attention.

The score sheet (Table 3) had 12 characteristics, 11 of which were scored from 0 to 8 or 8 to 0, while grade, a general acceptability rating, was scored 4 to 0. Descriptive terms such as "very good", "good", etc. were attached to the even numbers only.

Experience showed that no more than 4–6 samples, preferably 3, should be tasted at one sitting and that the best time for tasting was before the midday meal.

All but 2 of the 12 characteristics are self-explanatory. "Pressure-cooked flavour" is used to describe a bitter flavour developed in pressure-cooked meat, while "woolliness" is an undesirable texture effect describing the matting of fibres and is likened to chewing a piece of cotton wool.

(v) *Total Solids Loss*.—The cooking liquors were weighed after separation of the fat and a representative sample was taken. Two 20-ml portions were added to two tared moisture tins containing 1–2 g of dried asbestos and weighed. The liquors were mixed with the asbestos, the excess water was evaporated on a boiling water bath, and finally they were dried in an air oven at a temperature of 212°F for 16 hr. The results were expressed as ounces of solids lost per pound of uncooked meat.

## III. Results

### (*a*) *First Section*

The data were examined for normality of distribution and homogeneity of variance (Snedecor 1946, p. 249); where these assumptions were justified, analysis of variance in the form of split-plot design (Snedecor 1946, p. 309) was carried out.

The tasting data obtained from a panel of four tasters in respect of the grade, mince, and drying treatments were examined and reduced to mean scores for individual cooking methods in each of the three examinations. Such means are shown for all 12 quality characteristics in Table 4; the overall means are for the three examinations combined. Where comparisons are possible and the cooking methods are significantly different, the level of significance and the least difference between individual means for significance at that probability are also shown. Individual comparisons between cooking methods must be made with due care.

(i) *Meat Flavour*.—The overall means for cooking methods were not compared because of heterogeneity of variance.

The general order of intensity for each removal was low-pressure steam cooking, short and long water cooking, and high-pressure cooking. When concentrated cooking liquors have been added to the mince a score of 4 for meat flavour is considered satisfactory. Here, where no liquors have been added, the means fall short of this mark and this probably makes off-flavours more apparent.

(ii) *Stale Flavour*.—The high-pressure method appeared to give considerably less stale flavour than the other three methods after 3 months' storage. A score of 2·1 would, in terms of the scale, be described as slightly stale flavour.

TABLE 4

FIRST SECTION: MEAN VALUE FOR COOKING METHODS AND QUALITY CHARACTERISTICS

| Characteristic | Storage Time | Means for Cooking Methods 1 | 2 | 3 | 4 | Level of Significance: Probability (%) | Least Sig. Diff. at $P$ of Previous Column (Based on 48 D.F.) |
|---|---|---|---|---|---|---|---|
| Meat flavour | Initial | 2·0 | 2·8 | 3·8 | 2·7 | 0·1 | 0·76 |
| | 1 Month | 1·4 | 2·1 | 3·0 | 2·0 | 0·1 | 0·68 |
| | 3 Months | 1·0 | 1·9 | 2·7 | 1·9 | 0·1 | 0·48 |
| | Overall | 1·5 | 2·3 | 3·2 | 2·2 | — | — |
| Stale flavour | Initial | 0·1 | 0·4 | 0·3 | 0·4 | — | — |
| | 1 Month | 0·2 | 0·7 | 0·6 | 0·8 | 0·1 | 0·41 |
| | 3 Months | 0·7 | 2·1 | 2·1 | 2·6 | — | — |
| | Overall | 0·3 | 1·1 | 1·0 | 1·3 | — | — |
| Pressure-cooked flavour | Initial | 2·4 | 0 | 0 | 0 | — | — |
| | 1 Month | 2·9 | 0 | 0 | 0 | — | — |
| | 3 Months | 3·2 | 0 | 0 | 0 | — | — |
| | Overall | 2·8 | 0 | 0 | 0 | — | — |
| Burnt flavour | Initial | 0·7 | 0 | 0·2 | 0 | — | — |
| | 1 Month | 0·7 | 0·1 | 0·2 | 0·1 | — | — |
| | 3 Months | 1·0 | 0·1 | 0·2 | 0·2 | — | — |
| | Overall | 0·8 | 0·1 | 0·2 | 0·1 | 0·1 | — |
| Foreign flavour | Initial | 0·1 | 0·2 | 0·2 | 0·3 | — | — |
| | 1 Month | 0·1 | 0·3 | 0·5 | 0·4 | — | — |
| | 3 Months | 0·1 | 0·4 | 0·5 | 0·5 | — | — |
| | Overall | 0·1 | 0·3 | 0·4 | 0·4 | 0·1 | 0·20 |
| Particle size | Initial | 6·6 | 5·5 | 5·2 | 5·3 | 0·1 | 0·36 |
| | 1 Month | 6·5 | 5·4 | 5·5 | 5·4 | — | — |
| | 3 Months | 6·5 | 5·3 | 5·3 | 5·5 | — | — |
| | Overall | 6·5 | 5·4 | 5·3 | 5·4 | 0·1 | 0·29 |
| Tenderness | Initial | 6·2 | 4·2 | 5·0 | 5·0 | 0·1 | 0·50 |
| | 1 Month | 6·1 | 4·1 | 4·5 | 4·9 | 0·1 | 0·50 |
| | 3 Months | 6·1 | 4·4 | 4·8 | 4·8 | 0·1 | 0·50 |
| | Overall | 6·1 | 4·2 | 4·8 | 4·9 | 0·1 | 0·38 |
| Juiciness | Initial | 4·9 | 4·8 | 5·3 | 5·0 | 0·1 | 0·39 |
| | 1 Month | 4·7 | 4·7 | 5·1 | 4·9 | 0·1 | 0·31 |
| | 3 Months | 4·6 | 4·3 | 4·6 | 4·5 | 5·0 | 0·22 |
| | Overall | 4·7 | 4·6 | 5·0 | 4·8 | 0·1 | 0·23 |
| Woolliness | Initial | 3·2 | 0·6 | 0·6 | 0·7 | 0·1 | 0·43 |
| | 1 Month | 3·3 | 0·4 | 0·7 | 0·7 | 0·1 | 0·42 |
| | 3 Months | 3·5 | 0·8 | 0·7 | 0·8 | 0·1 | 0·43 |
| | Overall | 3·3 | 0·6 | 0·7 | 0·7 | 0·1 | 0·30 |

TABLE 4—(*Continued*)

| Characteristic | Storage Time | Means for Cooking Methods 1 | 2 | 3 | 4 | Level of Significance: Probability (%) | Least Sig. Diff. at $P$ of Previous Column (Based on 48 D.F.) |
|---|---|---|---|---|---|---|---|
| Fatness | Initial | 3·6 | 4·0 | 4·1 | 4·0 | 0·1 | 0·26 |
| | 1 Month | 3·4 | 3·9 | 4·0 | 3·9 | 0·1 | 0·23 |
| | 3 Months | 3·6 | 3·8 | 3·9 | 3·7 | 0·1 | 0·24 |
| | Overall | 3·5 | 3·9 | 4·0 | 3·9 | 0·1 | 0·16 |
| Colour | Initial | 4·5 | 4·4 | 4·4 | 4·1 | 5·0 | 0·23 |
| | 1 Month | 4·9 | 4·7 | 4·6 | 4·4 | 0·1 | 0·34 |
| | 3 Months | 4·8 | 4·6 | 4·6 | 4·3 | 1·0 | 0·29 |
| | Overall | 4·7 | 4·6 | 4·5 | 4·3 | 0·1 | 0·26 |
| Grade | Initial | 2·9 | 3·5 | 3·7 | 3·4 | 0·1 | 0·37 |
| | 1 Month | 2·5 | 3·5 | 3·7 | 3·4 | 0·1 | 0·42 |
| | 3 Months | 1·6 | 2·3 | 2·5 | 2·0 | 0·1 | 0·66 |
| | Overall | 2·3 | 3·1 | 3·3 | 3·0 | 0·1 | — |
| Moisture (%) | Overall | 2·9 | 4·5 | 4·1 | 3·8 | 0·1 | 0·91 |
| Fat (%) | Initial | 29·6 | 35·3 | 35·0 | 34·9 | 0·1 | 3·84 |

Means from taste panel data are for 96 scores (storage times separately) and 288 scores over all storage times together. Means for moisture values are for 72 determinations, those for fats for 24.

(iii) *Pressure-cooked Flavour.*—The high-pressure method was the only one to receive any non-zero scores for pressure-cooked flavour. This flavour increased with time of storage and the difference between the initial and the 3 months' score was significant at the 1 per cent. level of probability. A score of 3 was described as slight to moderate.

(iv) *Burnt Flavour.*—Table 4 indicates a low level in scoring for burnt flavour, the scores for the high-pressure method of cooking being considerably greater than those of the other three methods.

(v) *Foreign Flavour.*—Again, scores were low but the high-pressure method gave scores considerably less than the others.

(vi) *Particle Size.*—The overall means for cooking methods were compared. Particles from the high-pressure method were larger than those of the other cooking methods.

(vii) *Tenderness.*—Average scores for the high-pressure method were assessed as "good to very good" while those for the other three methods scored "fair to good". The short cooking in water received the lowest scores.

(viii) *Juiciness*.—Low-pressure cooking in steam compared very favourably in terms of juiciness with the other three methods and was rated fair to good.

(ix) *Woolliness*.—The high-pressure method was considered to give rather woolly meat, while scores for other methods indicated a low level of woolliness.

(x) *Fatness*.—The high-pressure method gave slightly less fatty meat than the other methods.

(xi) *Colour*.—The meat resulting from prolonged cooking in water was slightly darker than freshly minced cooked meat; the low-pressure method and cooking in water for a short period were again slightly darker in colour, and the high-pressure method gave the darkest meat.

(xii) *Grade*.—Grade or general acceptability scores placed high pressure in an inferior position to the remaining methods, and there was a slight preference for cooking in low-pressure steam.

(xiii) *Fat and Moisture Percentages*.—The four methods of cooking gave values in the following general order (descending): short cooking in water; low-pressure steam; prolonged cooking in water; high-pressure steam.

### (*b*) *Second Section*

(i) *Comparison of Cooking Methods*.—The four cooking times for the separate methods were not the same throughout and this meant that a complete split-plot analysis could not be made using all the factors of the experiment.

For various reasons, only two panel members were present for all tastings and this reduced the reliability of the results. Agreement between the tasters was checked by examining the distribution of the differences in scores for identical samples. These data suggested that the tasters were reasonably consistent, and there was no apparent variation associated with cooking methods.

The first consideration was to compare the 16 cooking methods. This was done by using the mean scores obtained by averaging over the four cooking times, three removals, and two tasters for each replicate in each cooking method; this must be considered in the interpretation of the results. It was reasonable to assume normality of distribution for such mean scores and use analysis of variance. In a few cases certain cooking methods had to be excluded from the analysis because all associated scores were zero. Where analysis of variance was made, the estimates of variance between replicates of cooking methods satisfied Bartlett's test for homogeneity, except for tenderness where the 16 methods were divided into two suitable groups of 13 and 3 before analysis.

The mean scores of each of the 16 cooking methods are shown for each of the 12 qualities in Table 5. The individual means were compared by Tukey's method (Tukey 1949), and the horizontal lines in the table show the division into homogeneous groups, using the probability level $P = 0{\cdot}05$. A few exceptions are discussed in the text.

(1) *Meat flavour*.—Method 7 is a straggler from its group and it is only possible to say that it is significantly better than some at least of the group 5 to 12 (Table 5).

(2) *Stale flavour.*—Methods 15 and 16 were stragglers from the other group and have a greater degree of stale flavour than some others.

(3) *Pressure-cooked flavour.*—Methods 1 and 5 were stragglers from the previous group. Methods 2 to 15 (Table 5) were excluded from analysis.

(4) *Burnt flavour.*—Methods 8 and 9 were excluded from analysis. The remaining 14 methods do not differ significantly between themselves at $P = 0{\cdot}05$.

(5) *Foreign flavour.*—Methods 9 and 12 were excluded from analysis because they gave zero estimates of error variance. Method 15 was a straggler from the remaining 13; it seems reasonable to place methods 9 and 12 in the latter group.

(6) *Particle size.*—Although methods 17 and 6 just failed to be cut off from the group of nine (Table 5), it was necessary to exclude them to leave a homogeneous group. Method 8 was a straggler from the group of methods 6 to 1 (Table 5).

(7) *Fatness.*—Methods 1 and 10 (Table 5) were stragglers from the large group (5 to 17).

(8) *Juiciness.*—Method 15 was a straggler from the large group (1 to 7) (Table 5).

Table 5

SECOND SECTION: MEANS FOR DIFFERENT METHODS OF COOKING AND QUALITY CHARACTERISTICS

All table entries are means of 72 scores. The horizontal bars divide the means into homogeneous groups which differ significantly at $P = 0{\cdot}05$. A few exceptions are discussed in the text

| Meat Flavour | | Stale Flavour | | Pressure-cooked Flavour | | Burnt Flavour | | Foreign Flavour | | Particle Size | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Method | Mean | Method | Mean | Method | Mean | Method | Mean | Method | Mean | Method | Mean |
| 8 | 1·17 | 1 | 0·61 | 2 | 0·00 | 8 | 0·00 | 13 | 0·03 | 15 | 5·71 |
| 10 | 1·81 | 9 | 0·76 | 8 | 0·00 | 9 | 0·00 | 6 | 0·04 | 12 | 5·81 |
| 1 | 1·90 | 5 | 0·88 | 10 | 0·00 | 10 | 0·01 | 9 | 0·04 | 18 | 5·90 |
| 5 | 2·21 | 7 | 0·94 | 12 | 0·00 | 13 | 0·01 | 12 | 0·04 | 16 | 6·29 |
| 13 | 2·25 | 6 | 0·96 | 13 | 0·00 | 18 | 0·01 | 3 | 0·06 | 13 | 6·32 |
| 15 | 2·28 | 17 | 1·04 | 15 | 0·00 | 3 | 0·04 | 10 | 0·06 | 7 | 6·33 |
| 9 | 2·29 | 3 | 1·12 | 3 | 0·03 | 7 | 0·04 | 14 | 0·06 | 9 | 6·36 |
| 2 | 2·32 | 12 | 1·14 | 7 | 0·08 | 6 | 0·07 | 2 | 0·08 | 2 | 6·39 |
| 6 | 2·33 | 10 | 1·17 | 9 | 0·18 | 12 | 0·07 | 8 | 0·08 | 3 | 6·44 |
| 17 | 2·47 | 13 | 1·17 | 16 | 0·18 | 2 | 0·08 | 18 | 0·08 | 6 | 6·85 |
| 16 | 2·49 | 2 | 1·24 | 18 | 0·26 | 1 | 0·11 | 5 | 0·10 | 17 | 6·89 |
| 18 | 2·49 | 14 | 1·25 | 6 | 0·68 | 16 | 0·11 | 7 | 0·10 | 14 | 7·25 |
| 14 | 2·53 | 8 | 1·26 | 14 | 0·83 | 17 | 0·11 | 17 | 0·10 | 5 | 7·29 |
| 3 | 2·56 | 18 | 1·29 | 17 | 1·07 | 15 | 0·12 | 16 | 0·12 | 10 | 7·32 |
| 12 | 2·61 | 16 | 1·60 | 5 | 1·36 | 5 | 0·19 | 1 | 0·17 | 1 | 7·54 |
| 7 | 2·83 | 15 | 1·68 | 1 | 1·61 | 14 | 0·25 | 15 | 0·28 | 8 | 7·72 |
| S.E.M. | ±0·106 | | ±0·161 | | ±0·140 | | ±0·053 | | ±0·052 | | ±0·204 |
| D.F. | 30 | | 32 | | 20 | | 28 | | 28 | | 32 |

TABLE 5—(*Continued*)

| Fatness | | Juiciness | | Tenderness | | Woolliness | | Colour | | Grade | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Method | Mean | Method | Mean | Method | Mean | Method | Mean | Method | Mean | Method | Mean |
| 8 | 3·11 | 8 | 2·58 | 15 | 3·17 | 10 | 0·00 | 13 | 4·26 | 1 | 2·28 |
| 1 | 3·50 | 10 | 3·65 | 13 | 3·72* | 8 | 0·10 | 7 | 4·29 | 8 | 2·31 |
| 10 | 3·57 | 15 | 4·24 | 8 | 3·92 | 13 | 0·62 | 6 | 4·32 | 15 | 2·36 |
| 5 | 3·74 | 1 | 4·28 | 12 | 4·24 | 12 | 0·78 | 16 | 4·35 | 5 | 2·50 |
| 6 | 3·79 | 13 | 4·46 | 2 | 4·56 | 15 | 0·88 | 5 | 4·42 | 16 | 2·62 |
| 15 | 3·79 | 5 | 4·51 | 18 | 4·78 | 3 | 1·14 | 10 | 4·42 | 14 | 2·65 |
| 9 | 3·82 | 2 | 4·60 | 3 | 4·79* | 7 | 1·26 | 9 | 4·43 | 17 | 2·68 |
| 12 | 3·82 | 3 | 4·65 | 9 | 5·03 | 2 | 1·57 | 2 | 4·50 | 10 | 2·75 |
| 2 | 3·85 | 16 | 4·67 | 16 | 5·04 | 6 | 1·88 | 17 | 4·58 | 13 | 2·75 |
| 13 | 3·86 | 17 | 4·69 | 10 | 5·12 | 18 | 1·89 | 8 | 4·60 | 18 | 2·75 |
| 3 | 3·88 | 6 | 4·71 | 17 | 5·14 | 16 | 2·21 | 3 | 4·61 | 6 | 2·78 |
| 14 | 3·88 | 18 | 4·72 | 6 | 5·24 | 14 | 2·22 | 14 | 4·74 | 12 | 2·92 |
| 16 | 3·89 | 12 | 4·75 | 5 | 5·32 | 9 | 2·25 | 18 | 4·82 | 2 | 3·03 |
| 18 | 3·90 | 14 | 4·75 | 7 | 5·32* | 5 | 2·50 | 1 | 4·88 | 3 | 3·07 |
| 7 | 3·93 | 9 | 4·79 | 1 | 5·69 | 1 | 2·81 | 12 | 4·99 | 7 | 3·32 |
| 17 | 3·93 | 7 | 4·83 | 14 | 5·85 | 17 | 2·88 | 15 | 5·53 | 9 | 3·33 |
| S.E.M. | ±0·073 | | ±0·125 | | ±0·365<br>±0·036* | | ±0·225 | | ±0·156 | | ±0·125 |
| D.F. | 32 | | 32 | | 26<br>6* | | 30 | | 32 | | 30 |

* See Section III(*b*)(i)(9).

(9) *Tenderness*.—Methods 13, 3, and 7 had very small variances and were analysed separately. The remaining 13 methods of cooking were analysed together; methods 15 and 8 were stragglers from the remaining 11 methods (Table 5). Method 13 was grouped with methods 15 and 8, and methods 3 and 7 with the 11 methods, by reason of their mean values. Further comparisons were made using the Fisher-Behrens test (Fisher and Yates 1953, p. 3); method 7 was not significantly different from methods 1 and 14, and method 3 gave more tender meat than method 13 and less tender than method 7.

(10) *Woolliness*.—Method 10 was excluded from analysis because all scores were zero. The other four groups (Table 5) were formed from the 15 methods because some methods were separated as stragglers, i.e. any one was significantly different from some at least in the adjacent group at $P = 0{\cdot}05$ or better.

(11) *Colour*.—Method 15 is separated from the remaining group (Table 5) by a gap.

(12) *Grade*.—Methods cut off from the main group (Table 5) were stragglers.

(13) *Fat content*.—The mean percentages for fat content are for initial material only and are listed in Table 6. Cooking methods 8, 10, and 1 were stragglers from the remaining group, but to make the two groups homogeneous it was necessary also to cut off 17.

The effect of an increase in cooking time was examined; it was associated with a decrease in fat content for those methods using steam, water, and fat as cooking media. Increase in pressure (or temperature) decreased the fat content in the groups of methods using steam and water but failed to attain significance in the group using fat.

TABLE 6

SECOND SECTION: MEAN VALUES FOR MOISTURE AND FAT CONTENTS AND TOTAL SOLIDS LOSS—INITIAL TIME

The horizontal bars divide the means into homogeneous subgroups

| Moisture Content (%) | | Fat Content (%) | | Total Solids Loss (oz/lb uncooked meat) | |
|---|---|---|---|---|---|
| Cooking Method | Mean | Cooking Method | Mean | Cooking Method | Mean |
| 1 | 2·5 | 8 | 22·9 | 12 | 0·16 |
| 5 | 2·6 | 10 | 26·7 | 15 | 0·16 |
| 6 | 2·7 | 1 | 28·6 | 17 | 0·20 |
| 17 | 2·7 | 17 | 30·4 | 18 | 0·20 |
| 14 | 2·8 | 5 | 31·4 | 10 | 0·23 |
| 9 | 2·8 | 14 | 31·5 | 3 | 0·25 |
| 2 | 3·3 | 6 | 33·7 | 7 | 0·25 |
| 3 | 3·3 | 9 | 33·9 | 16 | 0·26 |
| 16 | 3·4 | 16 | 36·1 | 6 | 0·27 |
| 13 | 3·6 | 2 | 36·5 | 14 | 0·28 |
| 7 | 3·7 | 3 | 37·7 | 13 | 0·28 |
| 18 | 3·8 | 12 | 38·0 | 5 | 0·30 |
| 15 | 4·0 | 18 | 38·4 | 2 | 0·33 |
| 8 | 4·1 | 7 | 38·9 | 1 | 0·35 |
| 12 | 4·4 | 13 | 39·2 | 9 | 0·36 |
| 10 | 4·8 | 15 | 40·0 | 8 | 0·41 |
| n′* | 24 | n′ | 6 | n′ | 12 |
| S.E.M.† (d.f.) | ±0·34(30) | S.E.M. (d.f.) | ±2·09(30) | S.E.M. (d.f.) | ±0·028(3) |

* Number of determinations used in mean.

† Standard error of the mean.

(14) *Moisture content.*—The mean percentages for moisture content for initial material only are listed in Table 6. Cooking methods 12 and 10 were cut off as stragglers; although methods 15 and 8 just failed to be stragglers it was necessary to cut them off to make the main group homogeneous. The regression coefficients of moisture content on storage time for the 64 classes for methods and cooking times were heterogeneous. The mean regression, however, was certainly real; as a first approximation the rate of increase in moisture per cent. per month may be taken as 0·041 ± 0·0034 (on 63 degrees of freedom).

(15) *Total solids loss.*—Methods 2, 1, 9, and 8 (Table 6) were cut off as stragglers and methods 12 and 15, the next most straggling, were excluded to make the main group homogeneous.

There was a dependence (significant at $P = 0{\cdot}01$) of flavour on solids loss between cooking methods over all the methods; this relationship was such that methods associated with high losses of solids had relatively low flavour scores.

TABLE 7

SECOND SECTION: MEAN VALUES FOR STORAGE TIMES AND QUALITY CHARACTERISTICS

All table entries are means of 24 scores

| Characteristic | Cooking Method | Storage Time | | | S.E.M.* (D.F. in Brackets) |
|---|---|---|---|---|---|
| | | Initial | 3 months | 6 months | |
| Stale flavour | 9 | 0·1 | 0·9 | 1·3 | — |
| | 7 | 0·0 | 0·9 | 1·9 | — |
| | 3 | 0·1 | 1·5 | 1·7 | — |
| | 2 | 0·1 | 1·1 | 2·5 | — |
| | 12 | 0·2 | 1·2 | 2·0 | — |
| Grade | 9 | 4·0 | 3·4 | 2·6 | — |
| | 7 | 4·0 | 3·4 | 2·6 | — |
| | 3 | 4·0 | 2·8 | 2·4 | — |
| | 2 | 4·0 | 3·2 | 1·9 | — |
| | 12 | 4·0 | 2·8 | 2·0 | — |
| Woolliness | 9 | 2·3 | 2·0 | 2·5 | ±0·18(16) |
| | 7 | 0·7 | 1·2 | 1·9 | — |
| | 3 | 1·0 | 0·9 | 1·5 | — |
| | 2 | 0·9 | 1·4 | 2·4 | — |
| | 12 | 0·8 | 0·2 | 1·3 | — |
| Meat flavour | 7 | 3·5 | 2·8 | 2·2 | ±0·16(12) |
| Particle size | 7 | 7·0 | 6·1 | 5·8 | ±0·22(4) |
| | 2 | 6·3 | 6·1 | 5·0 | ±0·18(4) |

* Standard error of the mean.

By classifying the methods into groups of similar members, it was found that for those methods using steam the dependence was marked, while for those using fat as a medium the relationship was absent.

Within the methods, the different durations of cooking often caused significant differences between the corresponding losses of solids; this effect was clearly significant when averaged over all the methods. The association of this loss with the flavour score for the corresponding material was significant when averaged over methods using steam, but not significant over any other group of methods.

The effect of increase in pressure (or temperature) on solids loss was examined; it was associated with an increase in solids loss for those methods using steam and water as cooking media, but the trend failed to attain significance for the methods using fat as a medium.

(ii) *Comparison of Cooking Times, etc.*—Examination of the results at this stage indicated that cooking methods 7, 9, 3, 2, and 12, warranted more detailed analysis. Analysis of variance was made where possible. In some other cases the distribution of scores was extremely restricted, and it was possible to classify the scores into two categories, such as zeros and non-zeros, and construct contingency tables. These were made with reference to experimental factors, such as cooking times, removal times, and tasters, and analysed by the use of $\chi^2$ analysis, assuming a binomial model. A condition for the validity of this procedure is that the minimum cell expectation is not too small, say not less than five (Fisher 1946, p. 84).

(1) *Staleness.*—It was appropriate to classify the scores as zeros and non-zeros; it was necessary to submerge certain factors and it was assumed that this was permissible (Simpson 1951). The differences between cooking times appeared to be not significant at $P = 0{\cdot}05$. The mean scores for the three storage times are listed in Table 7. Results for 3 months' storage were significantly higher (at $P = 0{\cdot}001$) than those from the initial examination, and the 6 months' values were higher than the 3 months' values (at $P = 0{\cdot}05$ or better) for all methods of cooking with the exception of method 3.

(2) *Grade.*—The classification of scores as four and less than four was convenient. The results were similar to those for stale flavour (Table 7). The scores for 3 months' storage were significantly lower (at $P = 0{\cdot}001$) than those for initial material, and those for 6 months' storage in turn significantly lower than for 3 months (at $P = 0{\cdot}01$ or better) except for method 3 and the latter comparison.

(3) *Woolliness.*—The distribution of scores permitted the use of analysis of variance for method 9 only. For method 12 the cooking times did not differ significantly (at $P = 0{\cdot}05$); the changes due to storage in the intervals initial to 3 months', and 3 months' to 6 months' storage, were significant (at $P = 0{\cdot}01$) (Table 7). For method 3 the cooking times were not significantly different, and only the change for the 3 months' to 6 months' storage was significant (at $P = 0{\cdot}01$). In method 7 the scores for the 6 months' storage time were significantly higher than for the 3 months' storage (at $P = 0{\cdot}05$) (Table 7); the cooking times were significantly different (at $P = 0{\cdot}05$), the difference favouring the shorter times (Table 8). The tasters differed about method 2 so that no reliable conclusions are possible. In method 9, there were no differences due to storage but the effects of cooking times differed significantly at $P = 0{\cdot}01$ (Table 8).

(4) *Meat flavour.*—The differences between removals were significant (at $P = 0{\cdot}001$) for method 7 only.

(5) *Particle size.*—Removal differences were significant (at $P = 0{\cdot}05$) for methods 7 and 2 only (Table 7).

(6) *Tenderness.*—The general trend was toward increased tenderness with increase in cooking time (Table 8) for data averaged over removals. This was

significant at $P = 0{\cdot}01$ for methods 9 and 3 and at $P = 0{\cdot}05$ for method 2. This trend was not significant (at $P = 0{\cdot}05$) in method 7.

(7) *Fat content (at initial time)*.—Only for method 2 did times of cooking have a significant effect (at $P = 0{\cdot}05$) (Table 8).

TABLE 8

SECOND SECTION: MEAN VALUES FOR COOKING PERIODS AND QUALITY CHARACTERISTICS

| Characteristic | Cooking Methods | Cooking Period | | | | n′* | S.E.M.† (D.F. in Brackets) |
|---|---|---|---|---|---|---|---|
| | | A | B | C | D | | |
| Woolliness scores | 9 | 1·2 | 2·0 | 2·7 | 3·2 | 18 | ±0·23 (6) |
| | 7 | 0·7 | 1·1 | 1·5 | 1·8 | 18 | — |
| Tenderness scores | 9 | 3·7 | 4·9 | 5·7 | 5·8 | 18 | ±0·20 (6) |
| | 3 | 3·8 | 4·6 | 5·2 | 5·6 | 18 | ±0·18 (6) |
| | 2 | 3·7 | 4·5 | 4·7 | 5·4 | 18 | ±0·24 (6) |
| Fat content (%) at initial time | 9 | 36·6 | 33·0 | 32·4 | 33·5 | 6 | — |
| | 7 | 38·6 | 38·9 | 39·3 | 38·8 | 6 | — |
| | 3 | 39·1 | 36·0 | 37·9 | 37·9 | 6 | — |
| | 2 | 39·4 | 36·2 | 35·0 | 35·4 | 6 | ±0·78 (6) |
| | 12 | 37·3 | 37·5 | 38·4 | 38·9 | 6 | — |
| Moisture content (%) | 9 | 4·0 | 2·4 | 2·4 | 2·5 | 6 | ±0·32 (6) |
| | 7 | 4·3 | 3·7 | 3·6 | 3·2 | 6 | — |
| | 3 | 4·4 | 3·5 | 2·9 | 2·6 | 6 | — |
| | 2 | 4·8 | 3·5 | 2·8 | 2·4 | 6 | ±0·20 (6) |
| | 12 | 4·4 | 4·2 | 4·5 | 4·7 | 6 | — |
| Total solids loss during precooking (oz/lb uncooked meat) | 9 | 0·33 | 0·34 | 0·38 | 0·41 | 3 | — |
| | 7 | 0·24 | 0·25 | 0·27 | 0·26 | 3 | — |
| | 3 | 0·21 | 0·26 | 0·26 | 0·27 | 3 | — |
| | 2 | 0·28 | 0·30 | 0·35 | 0·39 | 3 | ±0·011 (6) |
| | 12 | 0·12 | 0·15 | 0·19 | 0·17 | 3 | — |

* Number of values used in mean.

† Standard error of the mean.

(8) *Moisture content*.—The effects of the different cooking times were compared for the initial material (Table 8), and in only two methods, 9 and 2, were they significantly different (at $P = 0{\cdot}05$ for method 9 and at $P = 0{\cdot}001$ for method 2). The short cooking time was significantly different from the rest in method 9 and also in method 2.

(9) *Total solids loss during precooking*.—The effect of cooking time on solids loss was significant in method 2 only (at $P = 0{\cdot}01$).

### (c) *Third Section*

(i) *Ease of Boning*.—The optimum cooking time was defined as the minimum time permitting easy separation of the bones. There was little difference between the

TABLE 9

THIRD SECTION: MEAN VALUES FOR STORAGE TIMES AND QUALITY CHARACTERISTICS

| Characteristic | Part | Storage Time | | | n′* | Level of Significance: Probability (%) | Least Sig. Diff. at $P$ of Previous Column (D.F. in Brackets) |
|---|---|---|---|---|---|---|---|
| | | Initial | 3 Months | 6 Months | | | |
| Meat flavour | A | 2·5 | 2·1 | 1·9 | 24 | — | — |
| | B | 3·3 | 2·2 | 2·0 | 48 | — | — |
| | C | 2·9 | 2·3 | 2·0 | 48 | — | — |
| | D | 3·3 | 2·5 | 2·5 | 48 | 0·1 | 0·68 (16) |
| | E | 3·0 | 2·2 | 2·4 | 24 | 1·0 | 0·48 (8) |
| | F | 3·3 | 2·6 | 2·1 | 24 | 1·0 | 0·80 (8) |
| | | | | | | (3 and 6 months only) | |
| Stale flavour | A | 0 | 1·5 | 4·1 | 24 | — | — |
| | B | 0 | 1·6 | 3·1 | 48 | — | — |
| | C | 0 | 1·0 | 4·0 | 48 | — | — |
| | D | 0 | 1·0 | 2·9 | 48 | 1·0 | 1·41 (8) |
| | E | 0 | 0·9 | 2·5 | 24 | 1·0 | 1·60 (4) |
| | F | 0 | 0·8 | 3·7 | 24 | 1·0 | 1·84 (4) |
| Grade | A | 3·3 | 1·6 | 0·3 | 24 | — | — |
| | B | 3·9 | 2·3 | 0·7 | 48 | — | — |
| | C | 3·8 | 2·4 | 0·8 | 48 | — | — |
| | D | 4·0 | 2·8 | 1·6 | 48 | — | — |
| | E | 3·9 | 2·4 | 1·4 | 24 | — | — |
| | F | 4·0 | 2·7 | 0·9 | 24 | — | — |
| Moisture | A | 2·6 | 2·9 | 3·0 | 12 | 5·0 | 0·23 (8) |
| | B | 2·6 | 2·7 | 2·9 | 24 | 0·1 | 0·17 (16) |
| | C | 2·5 | 2·6 | 2·8 | 24 | 1·0 | 0·17 (16) |
| | D | 2·5 | 2·7 | 2·9 | 24 | 0·1 | 0·33 (16) |
| | E | 2·3 | 2·5 | 2·7 | 12 | 5·0 | 0·23 (8) |
| | F | 2·9 | 2·9 | 3·2 | 12 | n.s. | — |
| Pressure-cooked flavour | A | 0·9 | 1·8 | 1·8 | 24 | 0·1 | 0·81 (8) |
| | B | 0·2 | 0·6 | 1·8 | 48 | 1·0 | — |
| | C | 0·3 | 0·9 | 0·9 | 48 | ? | — |
| | D | 0·1 | 0·7 | 0·4 | 48 | 0·1 | — |
| | E | 0·3 | 1·3 | 0·8 | 24 | ? | — |
| | F | 0·2 | 0·9 | 0·3 | 24 | n.s. | — |

* Number of determinations used in mean.

2- and 4-in. pieces for ease of boning, but the boning operators found the 4-in. pieces slightly easier to handle. The approximate optimum cooking time for 2- and 4-in.

pieces with 3 lb/sq. in. of steam was 110 min; it was 150 min for pieces of the same size in steam at atmospheric pressure and 180 min for the large pieces in steam at atmospheric pressure.

(ii) *Examination of Data.*—The analytical panel consisted of four tasters. Their individual errors of scoring were estimated and tested for homogeneity by an approximate test (Ehrenberg 1950). Where the tasters showed homogeneity of variances, and the distribution of errors could reasonably be assumed normal, analysis of variance was conducted in the usual way, and with the usual interpretation; the parts of the experiment were examined separately. Where tasters' error variances differed significantly and the difference was evidently due to erratic scoring by a taster, the data for this taster were omitted.

(1) *Meat flavour.*—The treatments had no significant effects on meat flavour in the six parts A–F. In parts A–C there was significant taster × removal interaction which made the differences due to storage times difficult to establish and of uncertain significance. In the other parts (Table 9) meat flavour decreased significantly with increasing time of storage. Deterioration with increasing storage is suggested as a general tendency.

(2) *Stale flavour.*—No treatment effects produced significant changes in stale flavour in any part, except cooking times in part D (at $P = 0{\cdot}05$); the latter may be a chance effect. The interaction of tasters × removals made conclusions about the effect of removals difficult. However, for the interval between 3 and 6 months' storage, stale flavour increased with storage time (at $P = 0{\cdot}01$) in parts D–F; this was also true for parts A–C for some of the tasters. The effect of storage for 3 and 6 months compared with the initial material was significant in each case in all parts.

(3) *Pressure-cooked flavour.*—Difficulties of tasters in scoring this quality limit the conclusions from the analysis of the data. In most parts it was appropriate to make a dichotomy of scores into zero and non-zero categories and use $\chi^2$ analysis. Tests showed that size of piece was not significant, that a cooking time of 240 min in part C resulted in more pressure-cooked flavour than a time of 120 min (at $P = 0{\cdot}001$), and finally that pressure-cooked flavour tended to increase with time of storage (Table 9).

(4) *Grade.*—In parts B, C, and D, where cooking time was a factor, there was a tendency for meat cooked for a short time to be graded higher than meat cooked for a longer time; this effect was sometimes significant. The decrease in grade scores with increasing storage time was always significant at $P = 0{\cdot}001$ at least; not all tasters agreed about the extent of this deterioration, i.e. the significance of the change was much above $P = 0{\cdot}001$ for some panel members.

(5) *Moisture.*—Moisture determinations indicated a slight increase during the period of storage; this trend was significant in all parts except F.

## IV. Conclusions

### (a) *First Section*

Dried meat prepared by pressure cooking was different in a number of respects from the products prepared by atmospheric or near-atmospheric cooking. High-pressure cooking produced poor meat flavour; a low level of staleness (due to the

predominance of pressure-cooked flavour); good particle size lacking any meat structure (most of the collagen was converted to gelatin); and excessive tenderness giving rise to poor "chewability", dryness, "woolliness", and lack of fat. However, there was a slight preference for the low-pressure cooked meat as compared with the two methods of cooking in water.

### (*b*) *Second Section*

The number of methods compared was so great that statistical tests differentiated between them only with a limited precision and left some results inconclusive. There was a slight preference for the methods using low-pressure steam (3 and 7) as compared with the method using boiling water at atmospheric pressure (2). Methods of cooking using live steam at high pressures (1, 5, and 6) gave the same results as obtained in the first section, together with very strong burnt and foreign flavours.

The cooking methods with fat (14, 15, 16, 17, and 18) using high-pressure steam produced appreciable stale flavour; there was less pressure-cooked flavour than in the previous methods of pressure cooking; they resulted in considerable burnt and foreign flavours and they gave a very "woolly" texture.

The mince cooked with atmospheric steam (8) in water was low in meat flavour; had a very stale flavour; was fairly dry, tough, and lacking in fat. The mince in steam at atmospheric pressure (10) was flat in flavour, dry, and lacked fat, while cooking in water at 195°F (13) gave a product of similar characteristics with the exception that it was tough but had an adequate fat content.

The results obtained for loss of total solids during cooking suggest that at the same cooking temperature, cooking in water gave greater losses of total solids than cooking in steam. Cooked minces lost more solids than pieces of meat, and cooking in steam under pressure resulted in greater losses than pressure cooking in fat. Other factors being similar, an increase in cooking temperature resulted in a greater loss of total solids.

The results of the moisture and fat determinations indicate that the method of cooking largely determines the final moisture content indirectly through the fat content. Two notable exceptions to this general rule were the cooking methods of the minces (10 and 8) which had high moisture contents and low fat contents.

As a whole, the results yielded little information on the effect of cooking times on the various qualities but did show that the effects on storage were in accordance with expectations, i.e. increasing deterioration with increasing time of storage. The relationship between flavour and loss of total solids during cooking is relatively unimportant when concentrated cooking liquors are added back to the meat before drying.

### (*c*) *Third Section*

As pointed out earlier, this series of experiments was designed essentially to study ease of boning, and any further information obtained was extracted under difficulty owing to the nature of the experimental design.

The series, as a whole, indicates that cooking on the bone at or near atmospheric pressure will be unsuitable in commercial practice owing both to the length of time required for cooking and the subsequent damage to the product as a result of long cooking.

### (*d*) *General*

From these series of experiments it can be concluded that, in order to produce dried meat of good initial quality and of good keeping quality, the fresh meat should be boned before cooking, cut into pieces approximately 3 in. cube, and cooked for approx. 45 min in steam at atmospheric pressure; these conclusions are applicable to material from mature to aged beasts, for two-stage through-draught drying, when the cooking liquors are not returned to the mince.

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